The long-range WindScanner system – how to synchronously intersect multiple laser beams

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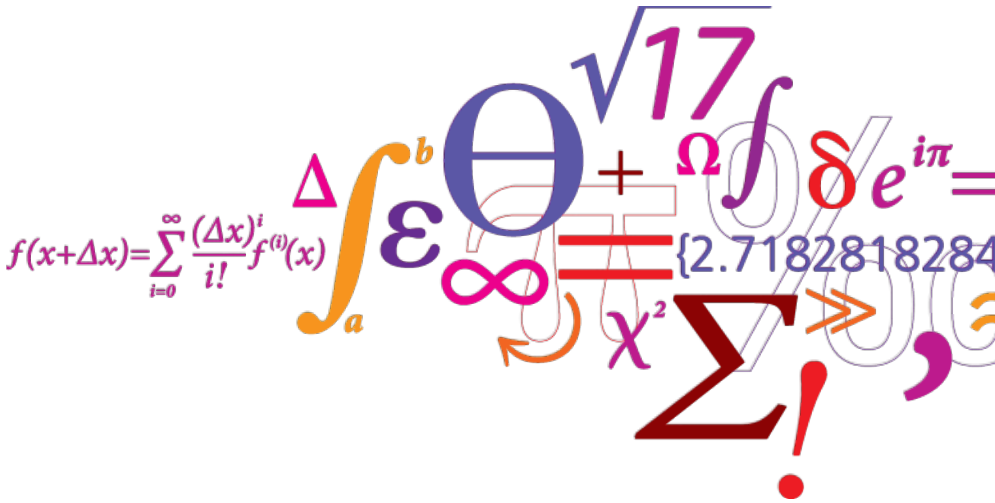
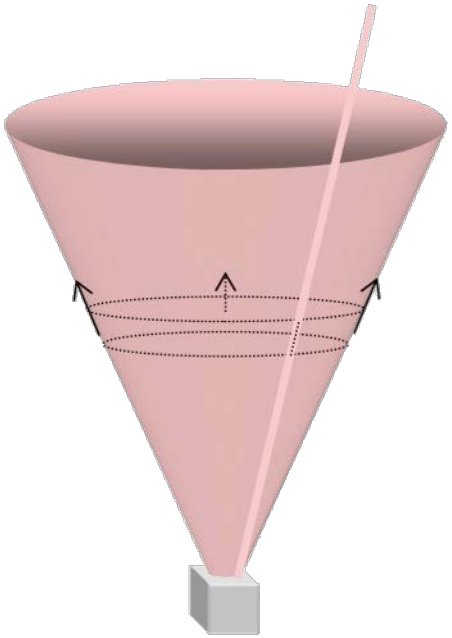
Michael Courtney, Jakob Mann and Torben Mikkelsen



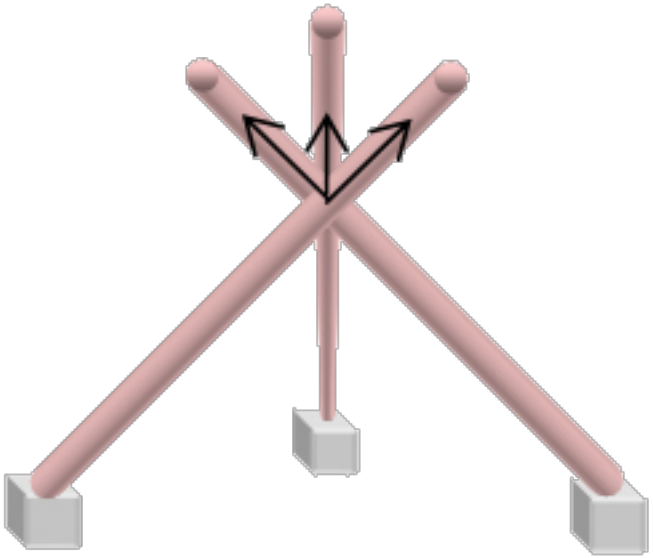
WindScanner.dk
DTU Wind Energy
Department of Wind Energy

WAUDIT
PEOPLE
MARIE CURIE ACTIONS
ValE
TeslaBox
CNR MAPPER

How to accurately measure 3D wind speed?

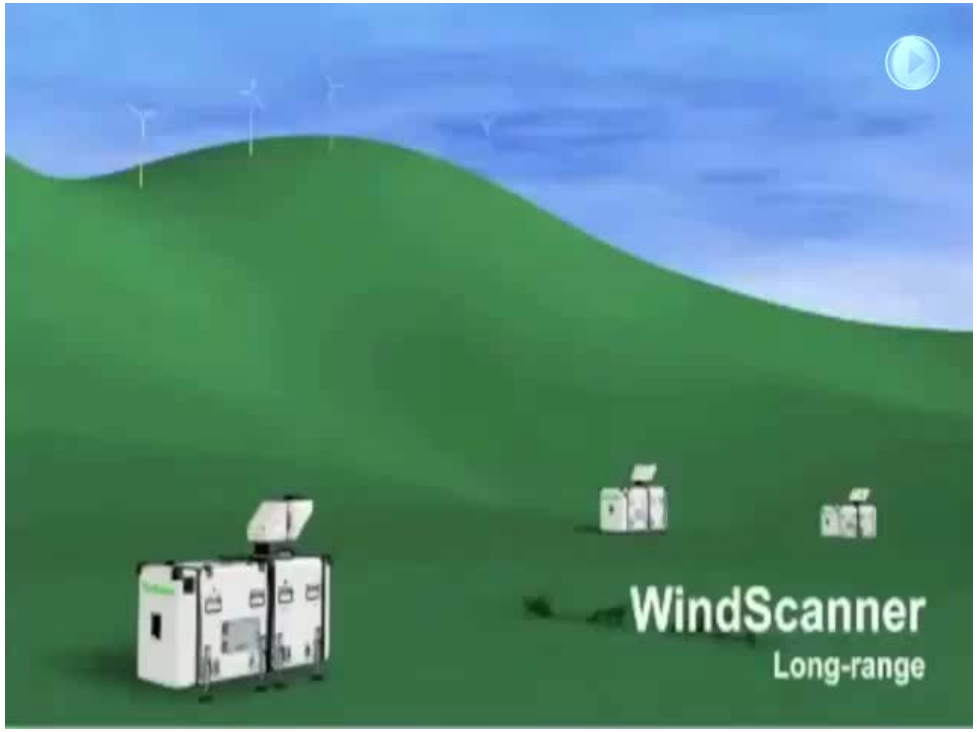


Single lidar:
needs the assumption of
the horizontal homogeneity of the flow



Multiple lidars system:
No assumptions

No assumptions = Multiple lidars system



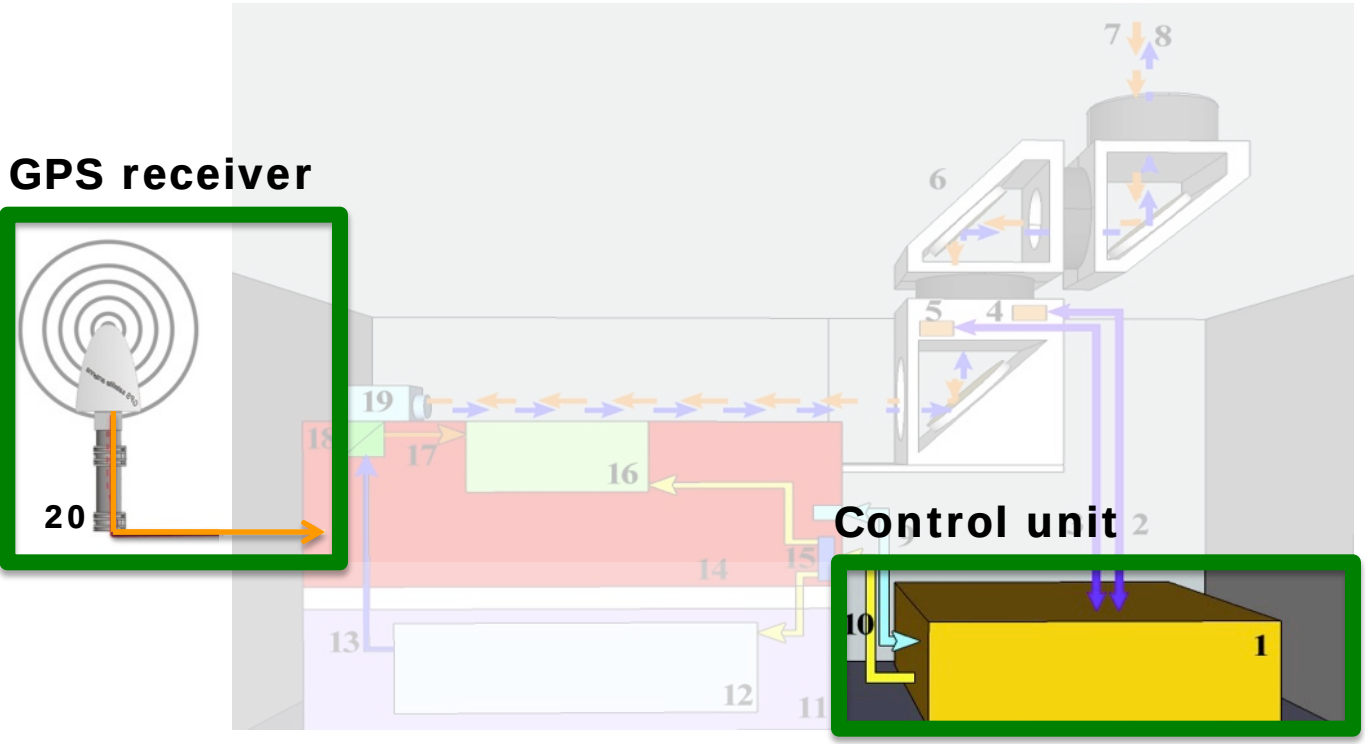
- Synchronization in steering and measurements
- Pointing accuracy and repeatability of trajectories

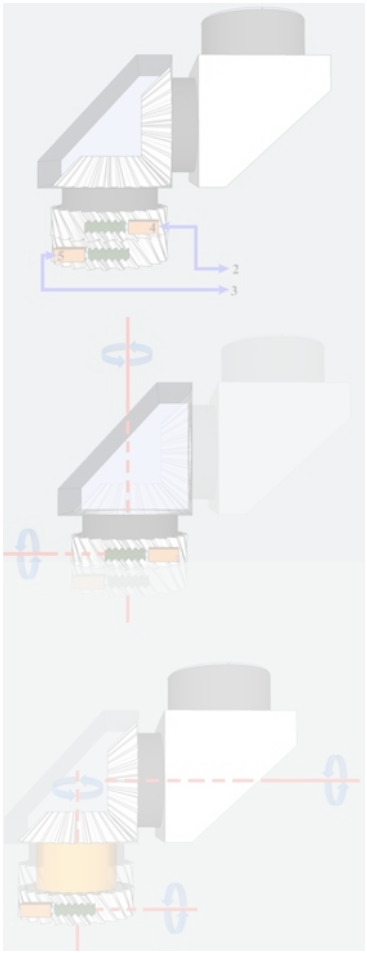
Long-Range WindScanner

A pulsed lidar
Maximum distance 5000 m

Hardware overview

Responsible for the synchronization

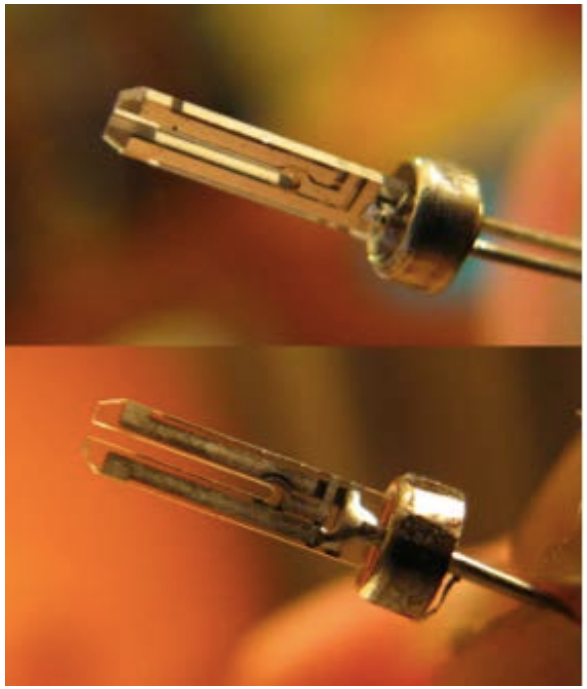




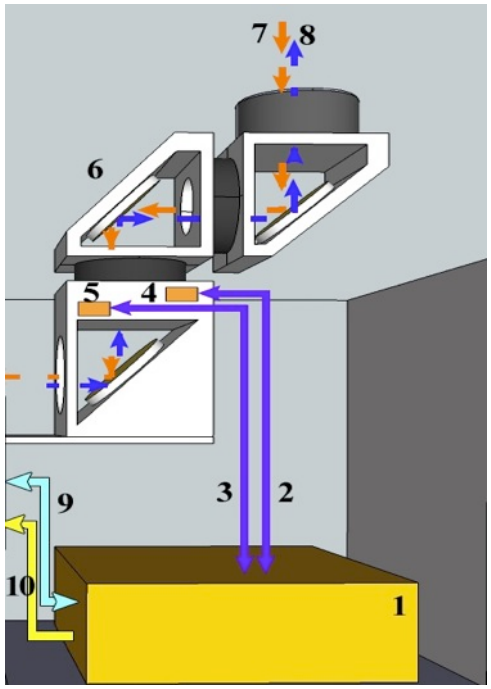
1 – motion control unit, 2-3 – power and position cables, 4 – azimuth motor, 5 – elevation motor, 6 – scanner head, 7,17 – backscatter 8,13 – laser pulses, 9 – USB connection, 10 – trigger signal, 11 – optical rack, 12 – laser source, 14 – lidar computer, 15 – trigger splitter, 16 – acquisition board, 18 – optical mixer, 19 – system of lenses, 20 – GPS receiver

The motion control unit of LRWS

- Commands the motion of the scanner head and an execution of the measurements
- It has a crystal clock oscillator as a source for timing of moves and triggers
- Interaction with the control unit is achieved by motion programs



Crystal clock oscillator



Scanner

```
OPEN PROG 1983 CLEAR
TriggerFrequency=10
#1(azimuth)->X
#2(elevation)->Y
TM1000
X90Y45

TM1000
TriggerPulses=10000
X90Y45

TM800
TriggerPulses=8000
X100Y50
DELAY0
CLOSE
```

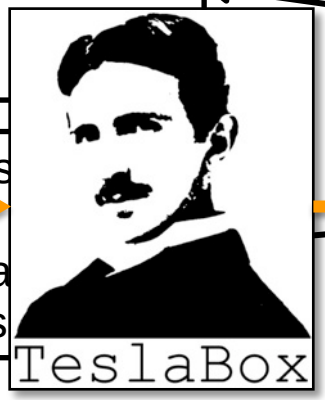
Motion program

How to setup a measurement scenario

Time move of 1s (1000 ms)
to the position:
x=azimuth=10°
y=elevation=35°

Standstill for 1s (1000 ms)
previous position while
10000 laser pulses and a
the same amount of backs

Motion for 800 ms to the position:
x=azimuth=100°
y=elevation=50°
while sending 8000 laser pulses and accumulating the same amount of backscatters



OPEN PROG 1983 CLEAR
TriggerFrequency=10
#1(azimuth)->X
#2(elevation)->Y
Header

TM1000
X90Y45

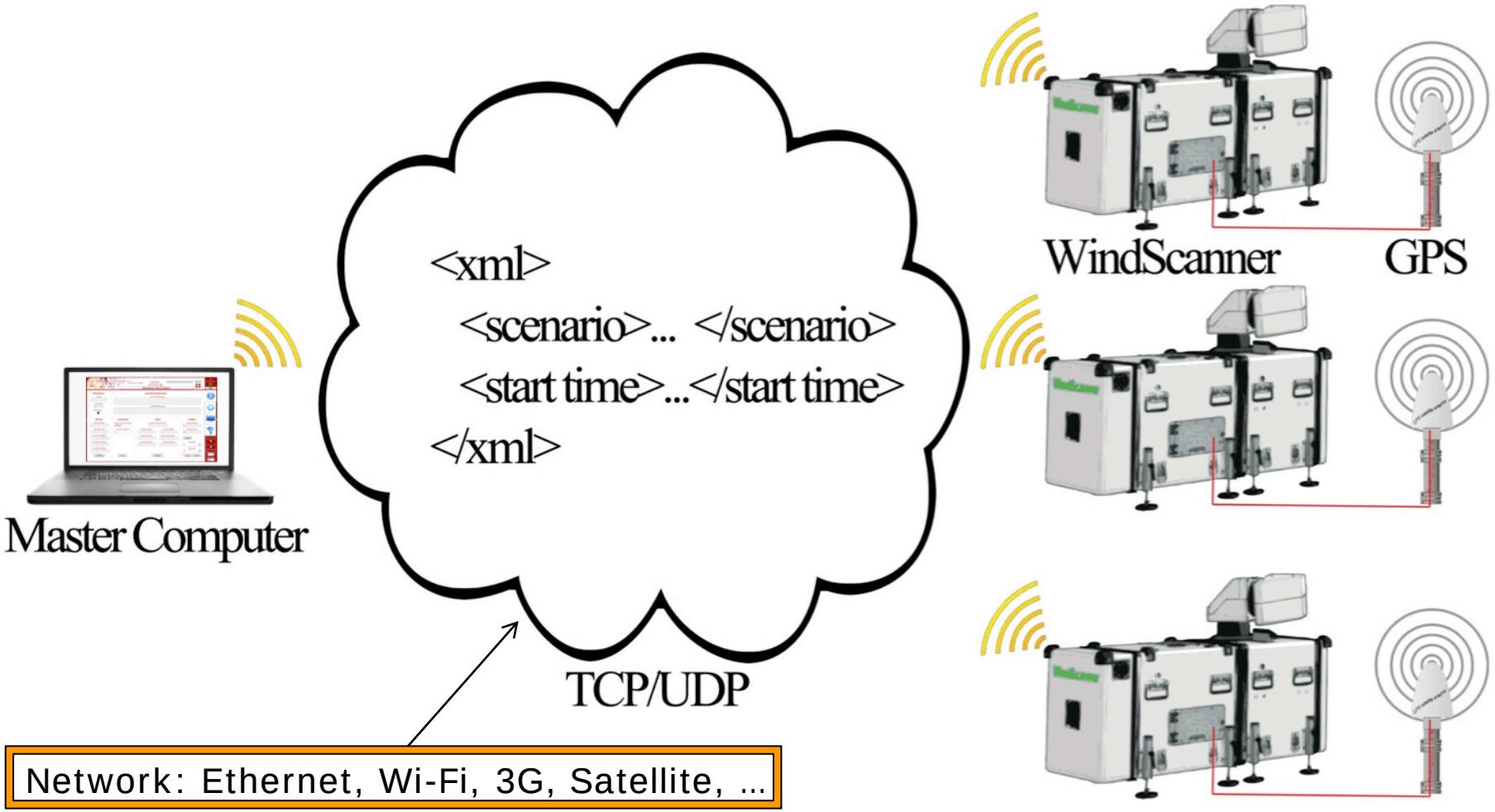
TM1000
TriggerPulses=10000
X90Y45

TM800
TriggerPulses=8000
X100Y50

Motion

DELAY0
CLOSE
Footer

The long-range WindScanner system



Lidar Communication Protocol (LidComPro)

TCP Commands

- 2100: GoHome
- 2200: GetGPS
- 2300: Synchronize
- 2400: GetConfiguration
- 2500: SetConfiguration
- 2600: GetPositions
- 2700: SetPositions
- 2800: GetScenario
- 2900: SetScenario
- 3000: Measure
- 3100: GetData
- 3200: Wipe
- 3300: GetCapabilities

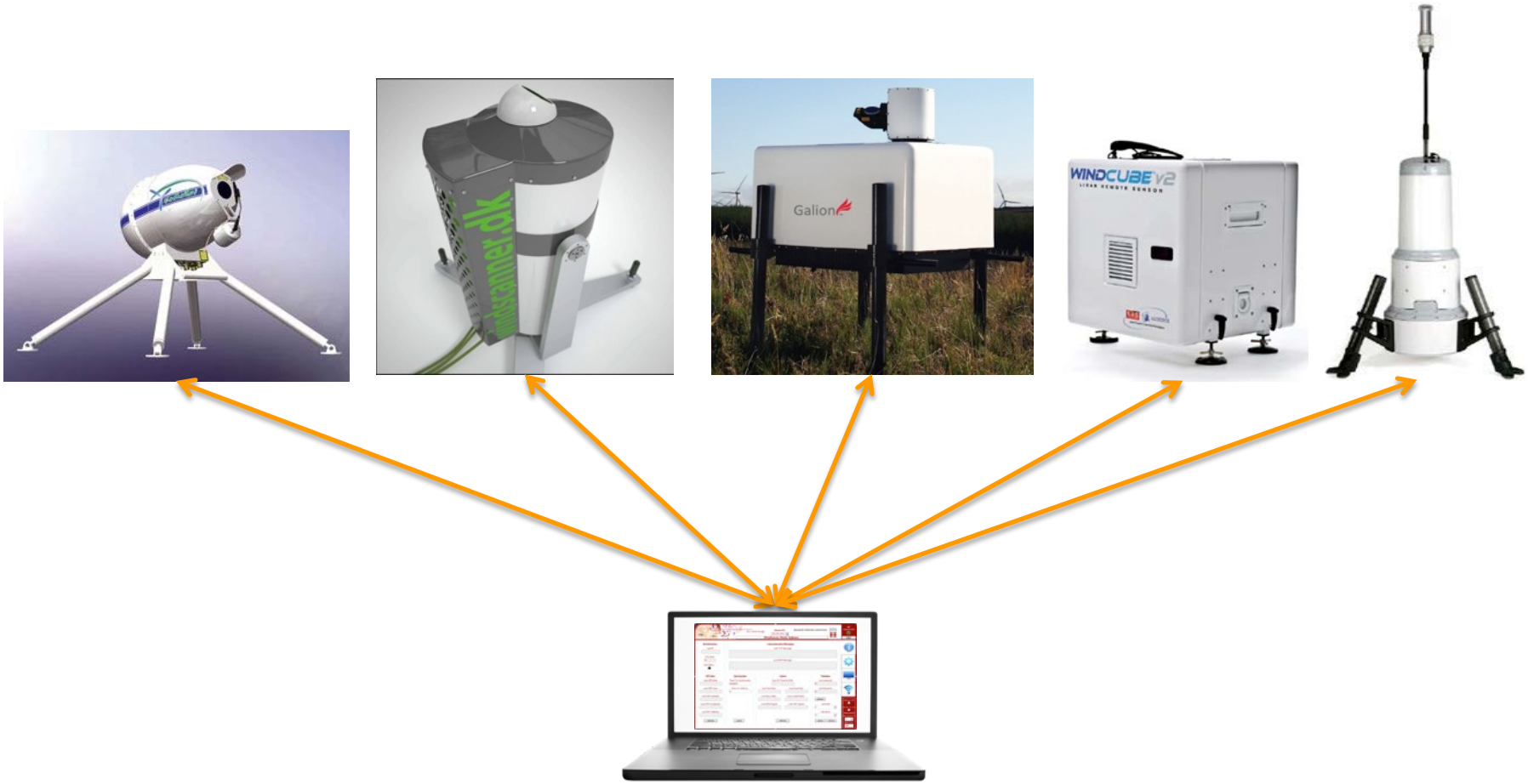
UDP Commands

- 1100: WhoIsThere?
- 1200: Abort
- 1300: Unlock
- 1400: Stop
- 1500: GetStates
- 1600: IsBusy?
- 1700: Shutdown
- 1800: Reset

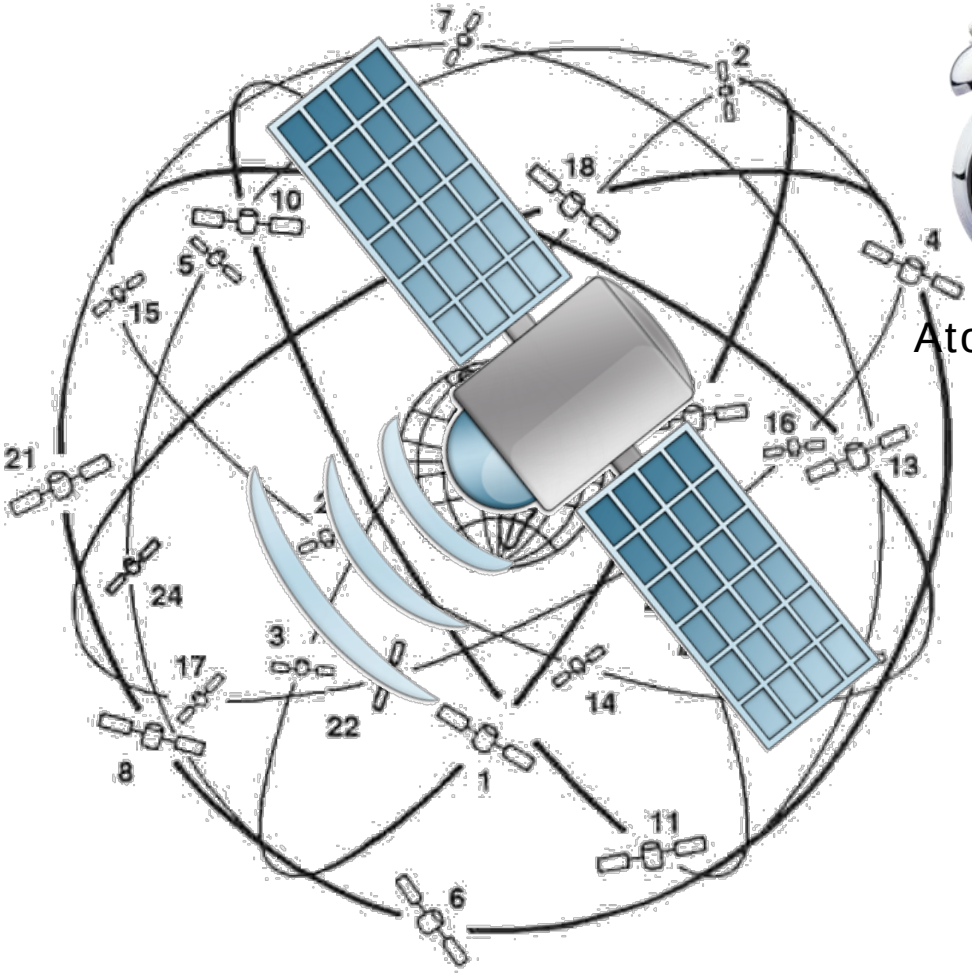
XML message example

```
<packet Client="Sterenn" PckNo="1.1" Cmd="2200" Alert="0">
        <time>080651.50</time>
        <date>270812</date>
        <lat>554134.5810N</lat>
        <long>120612.0170E</long>
        <alti>56.577352</alti>
        <msg></msg>
</packet>
```

What is our dream

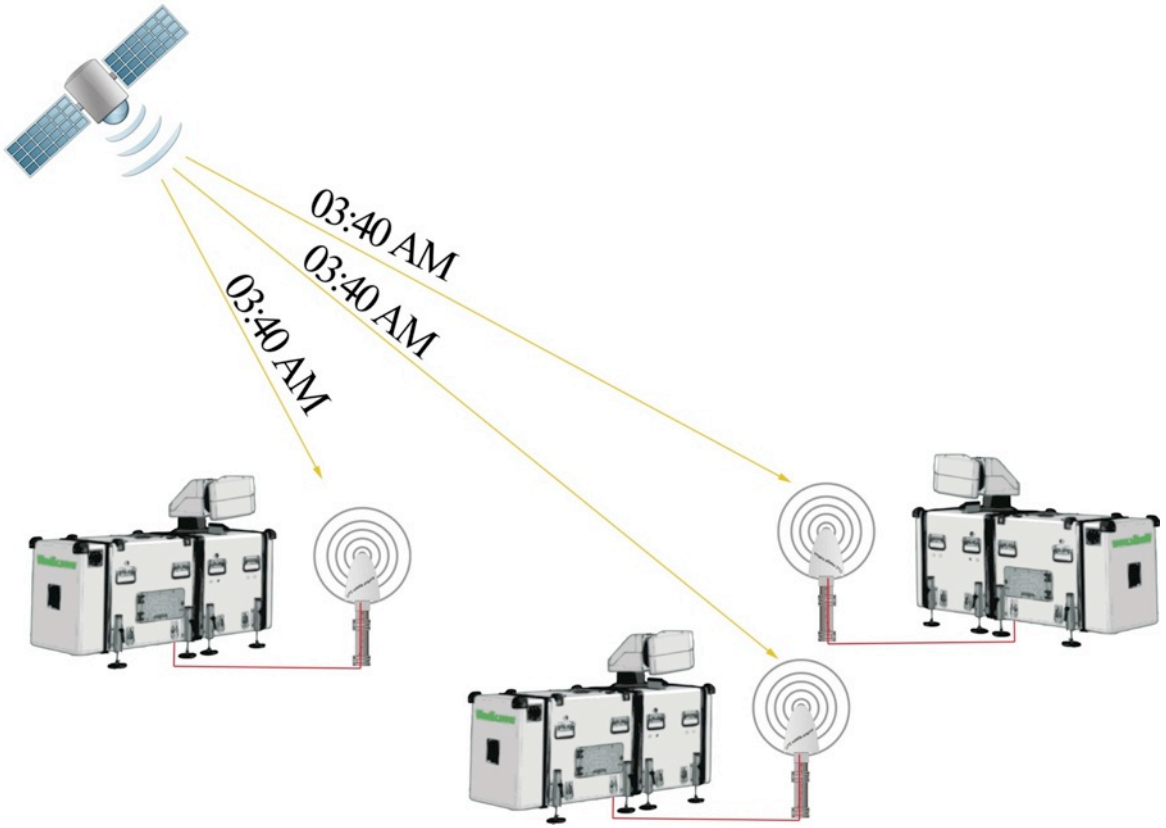


Global Positioning System



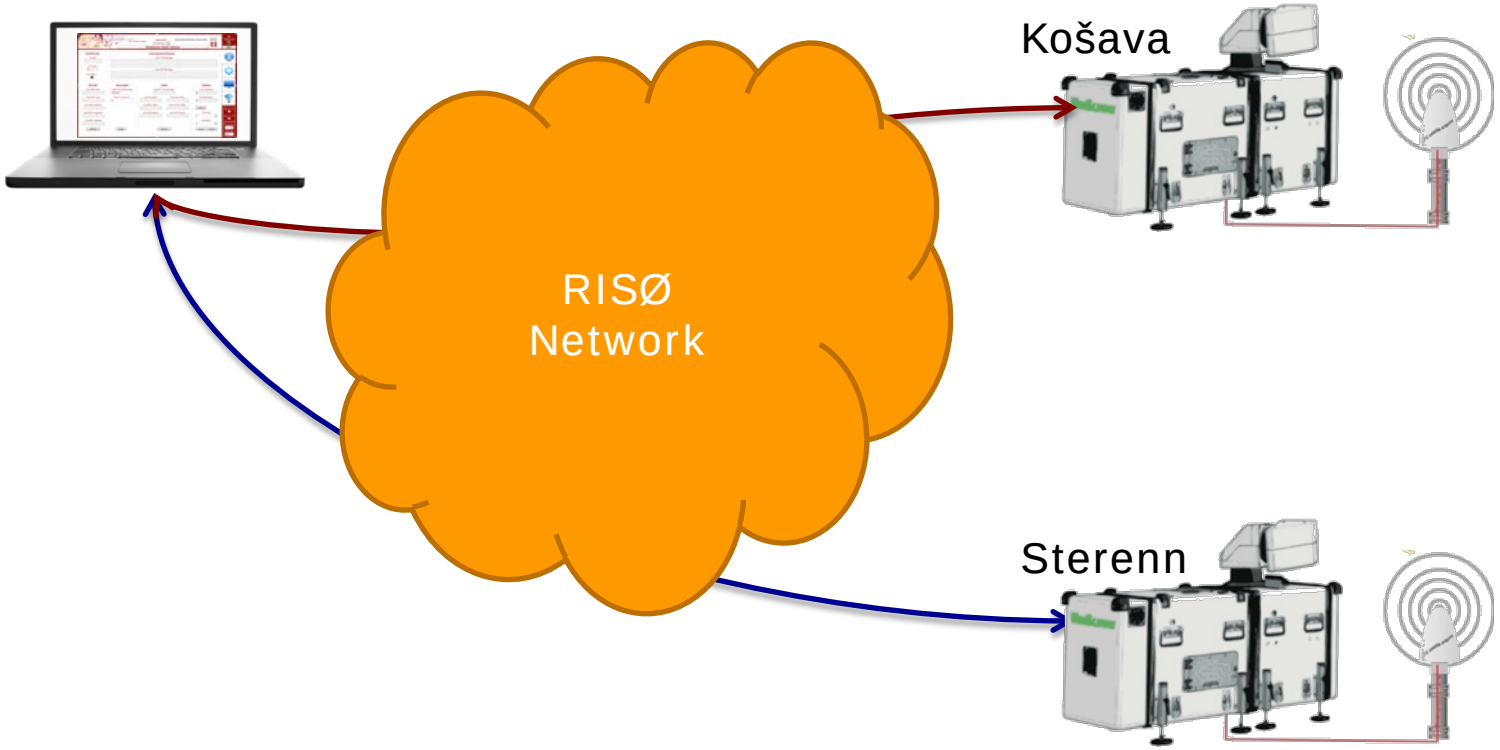
Atomic clock

Same time base



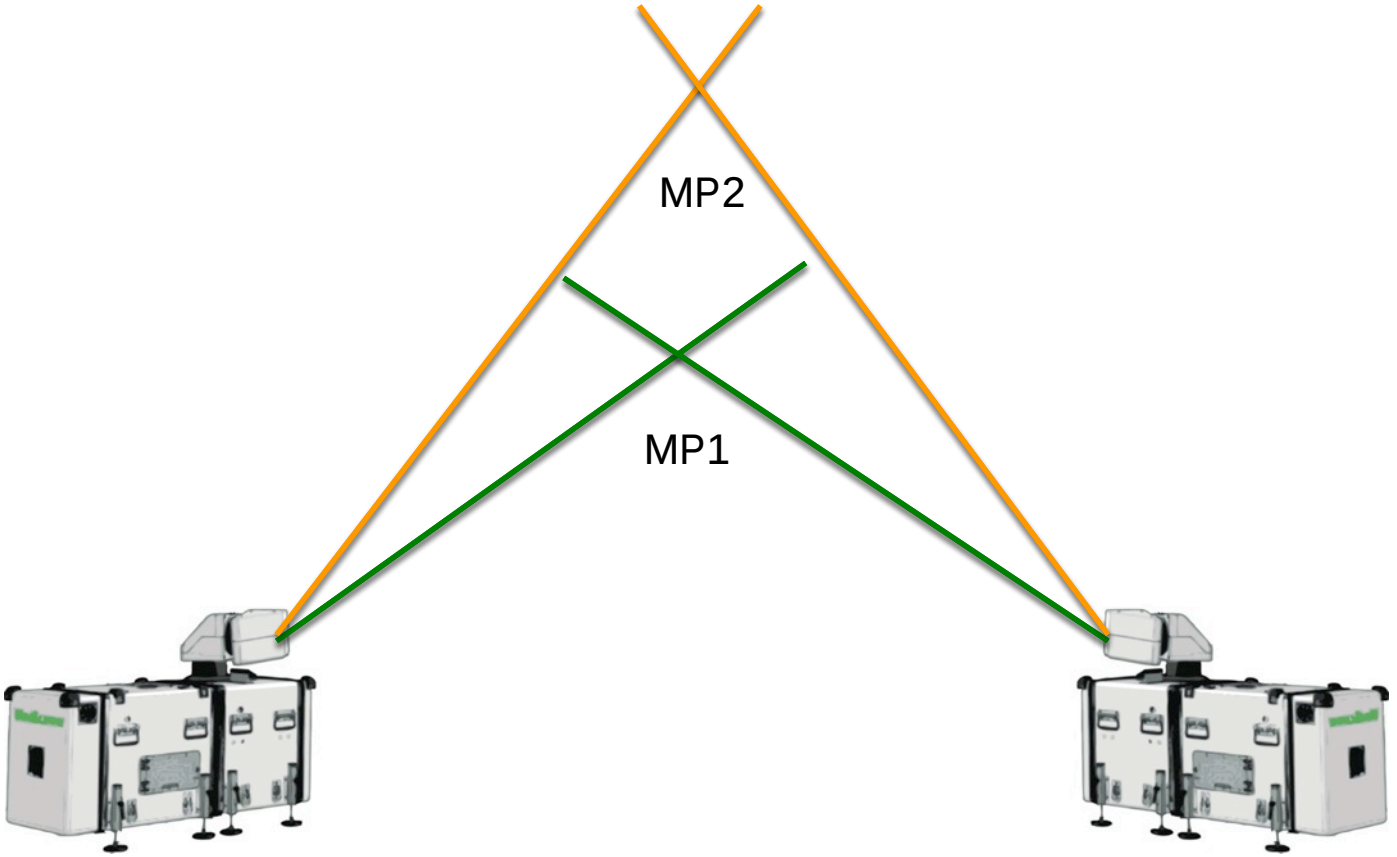
250 ns accuracy of the GPS clock

Test of the synchronization concept



- 4 hours, two measurement points, data collected after each measurement point, WindScanners monitored during the test

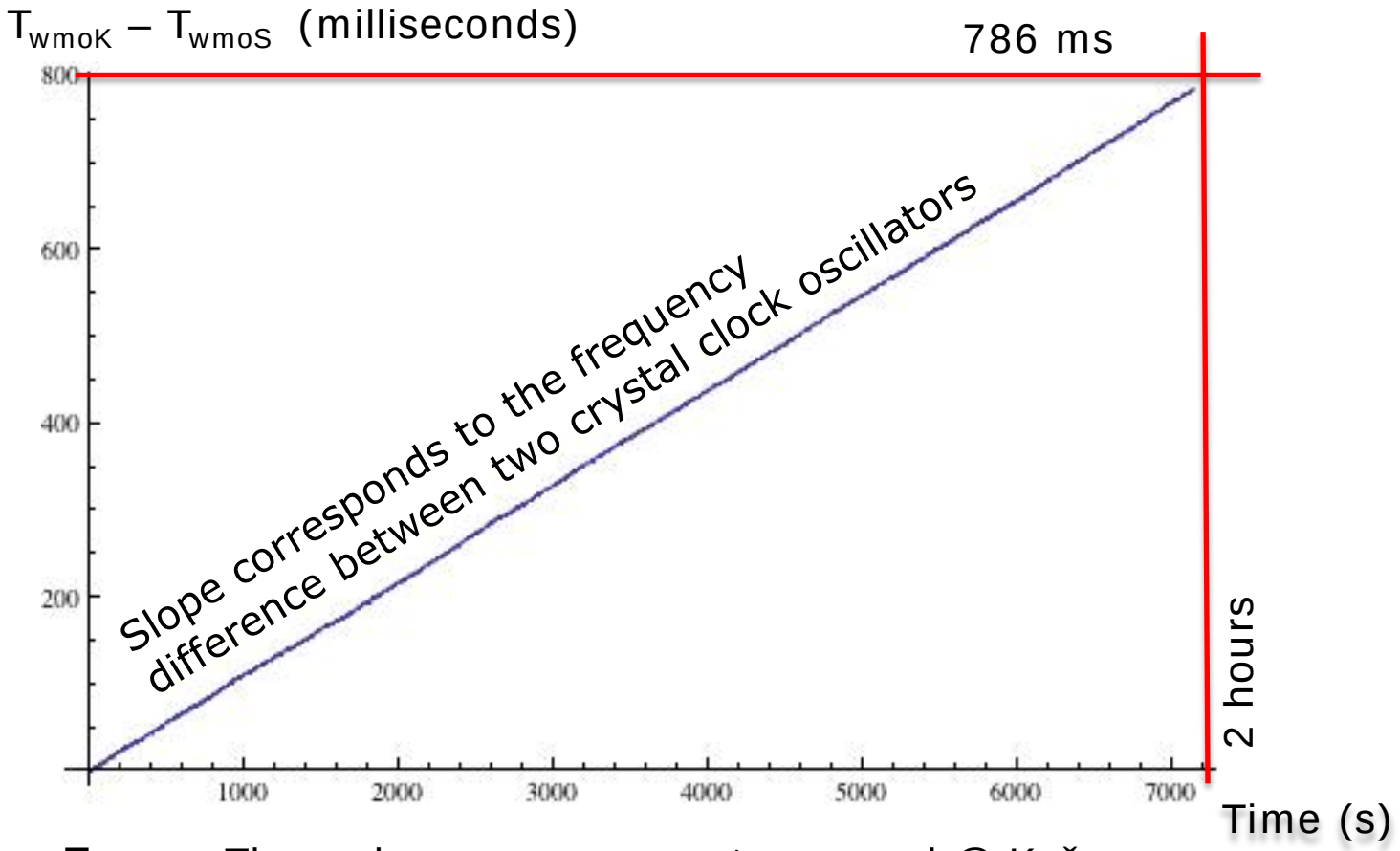
Two measurement points



Košava
MP1: azimuth/elevation 10°/10°
MP2: azimuth/elevation 20°/20°

Sterenn
MP1: azimuth/elevation -10°/10°
MP2: azimuth/elevation -20°/20°

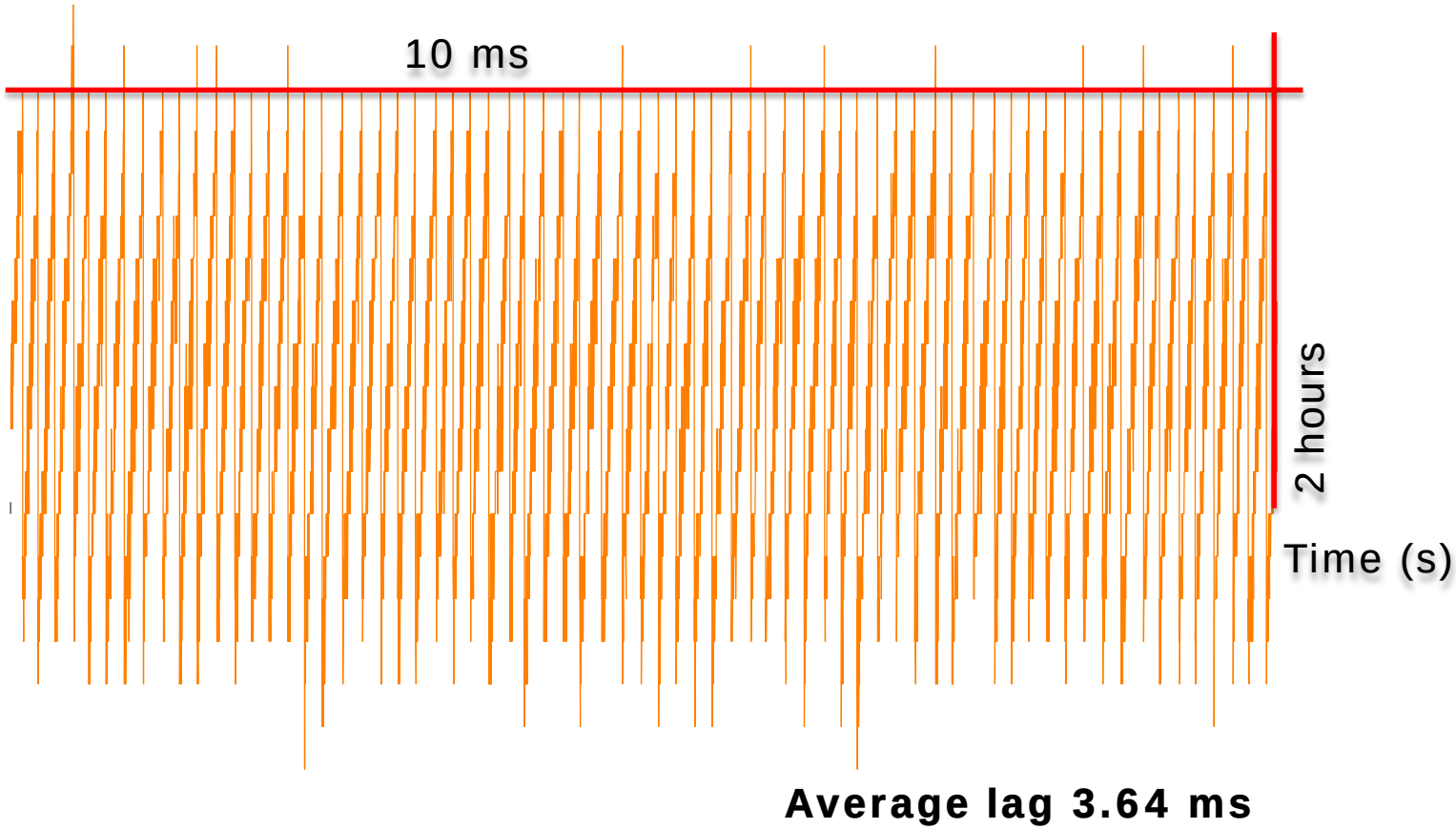
How much two devices lag from each other



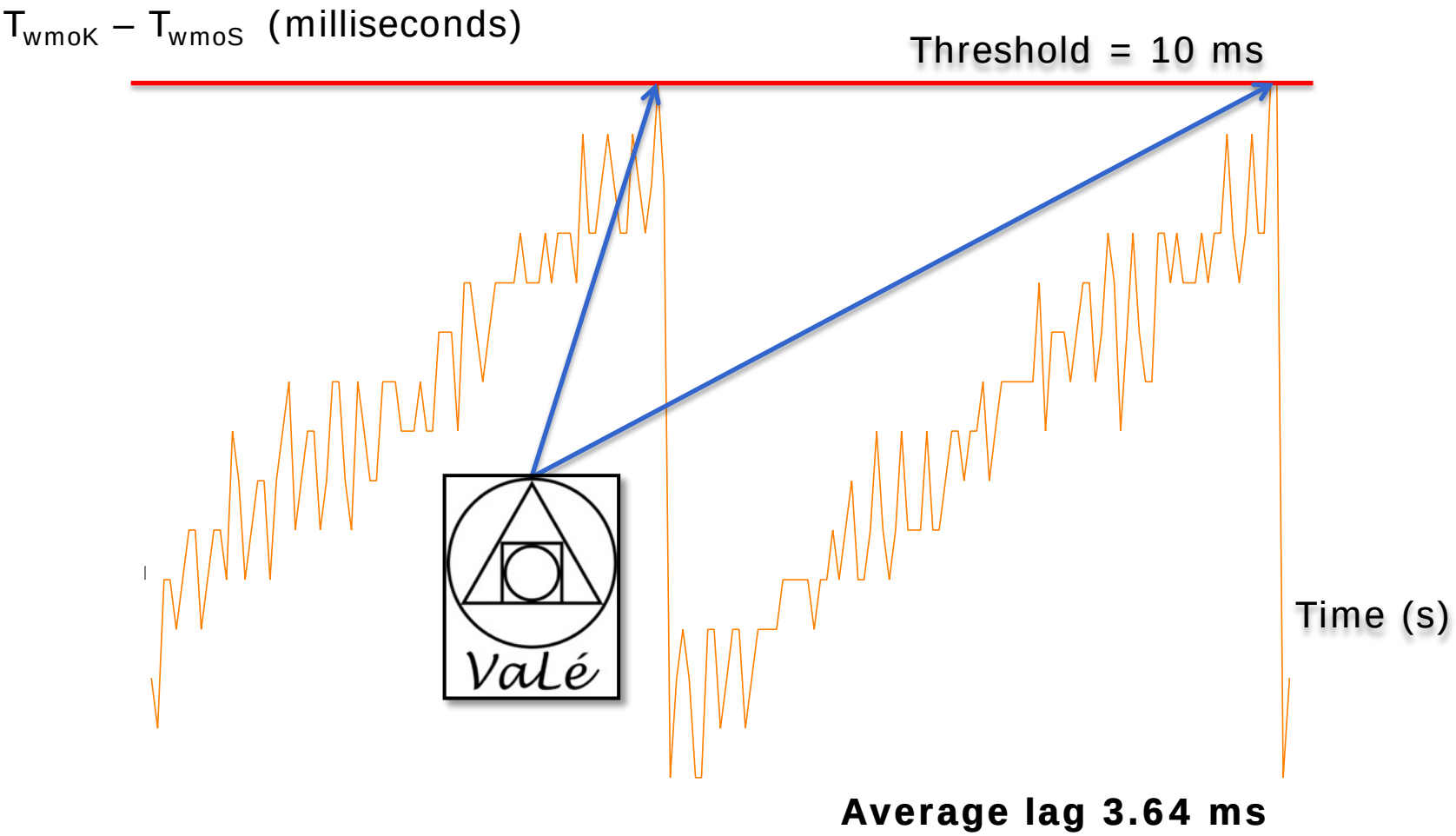
T_{wmoK} – Time when measurement occurred @ Košava
T_{wmoS} – Time when measurement occurred @ Sterenn

Results with “VaLé” compensator

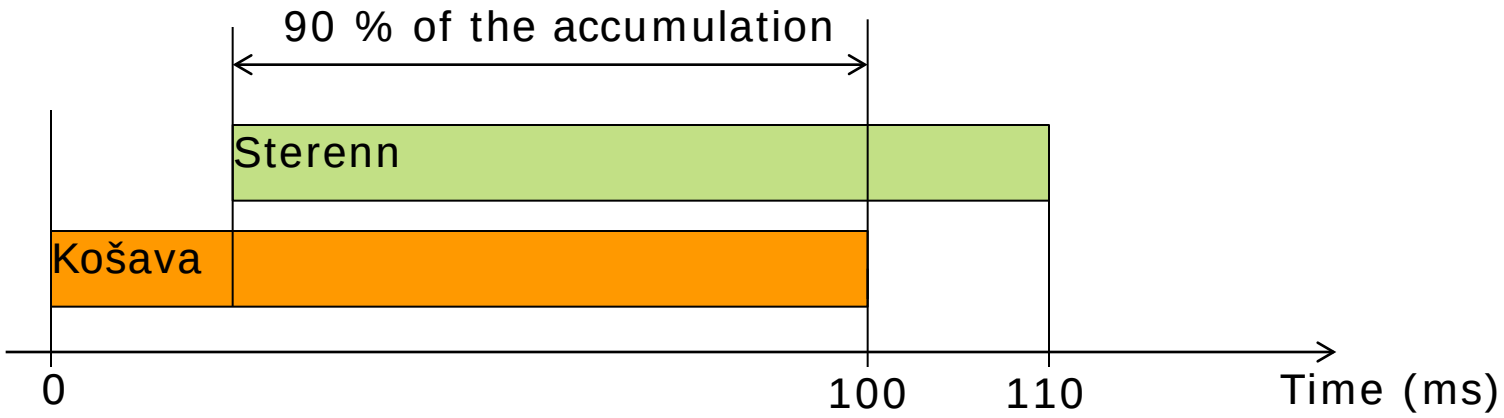
$T_{wmoK} - T_{wmoS}$ (milliseconds)



Results with “VaLé” compensator



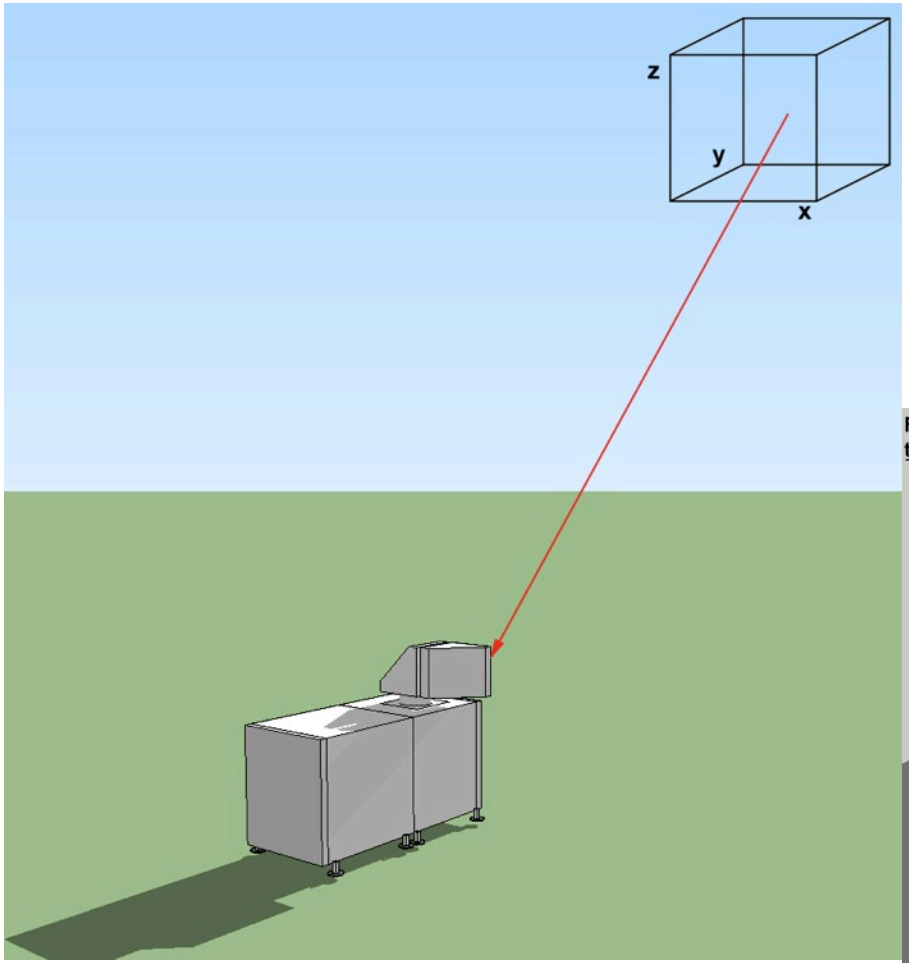
Consequence of the maximum lag



- This lag can be considered negligible since the windscanners minimum accumulation time is 100 milliseconds
- This is minimum time needed to accumulate enough Doppler spectra in order to provide reliable radial wind speeds.

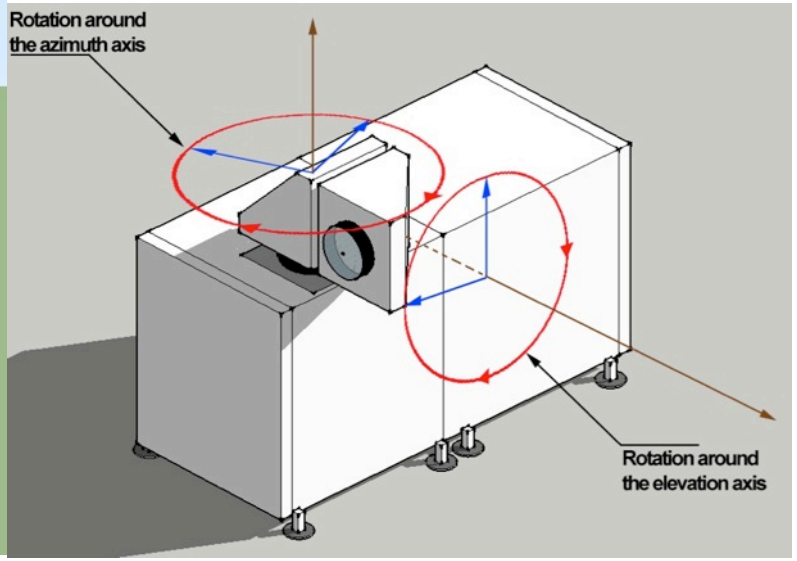
5 x LRWS in sync

WindScanner is as good as its pointing accuracy

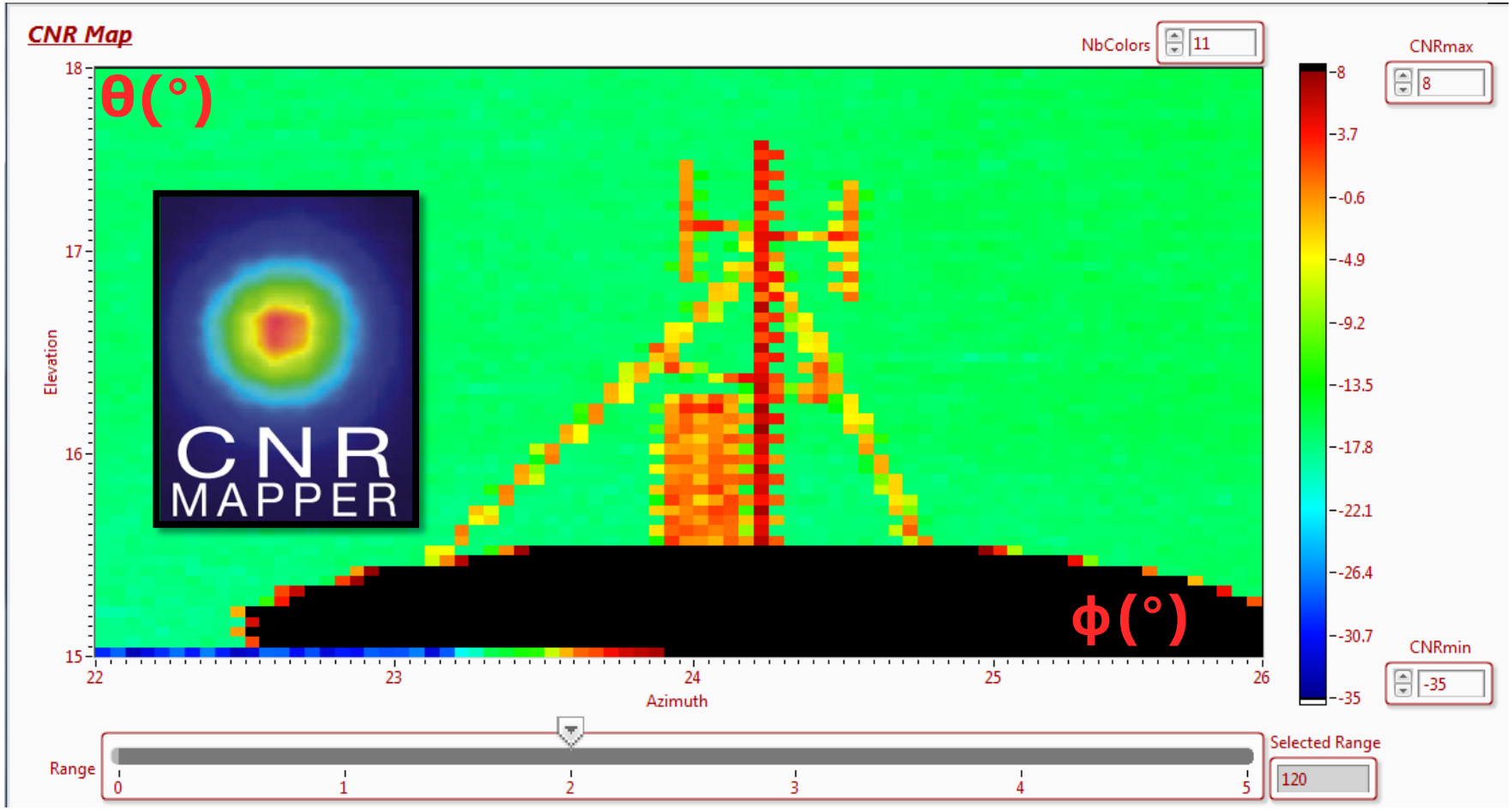


- Determine uncertainties for:
  - azimuth (ϕ)
  - elevation (θ)
  - range gate center position (r)

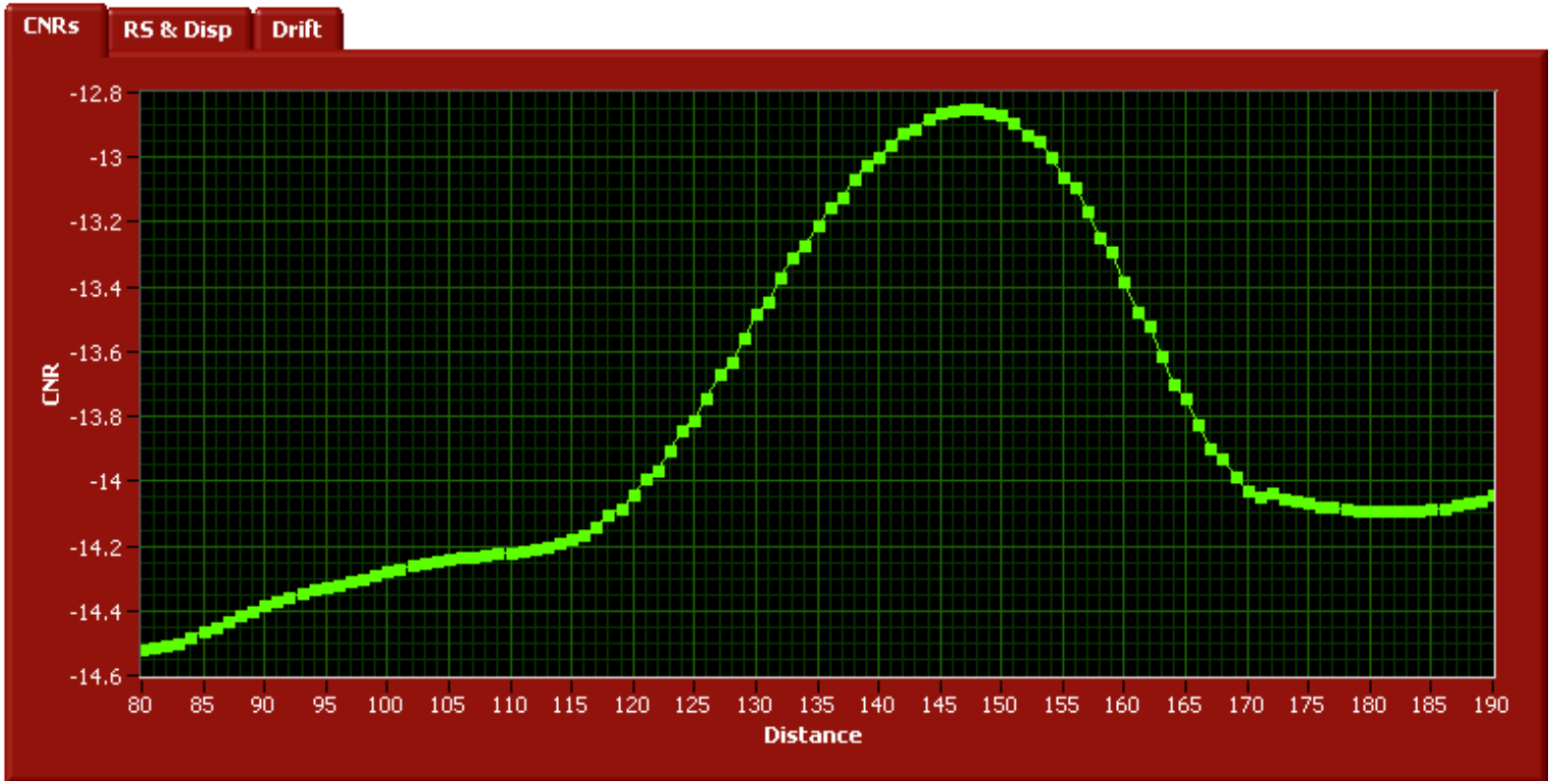
$(\phi,\theta,r) = (\phi \pm \Delta\phi,\ \theta \pm \Delta\theta,\ r \pm \Delta r)$



3D Plot of the intensity of the returned signal



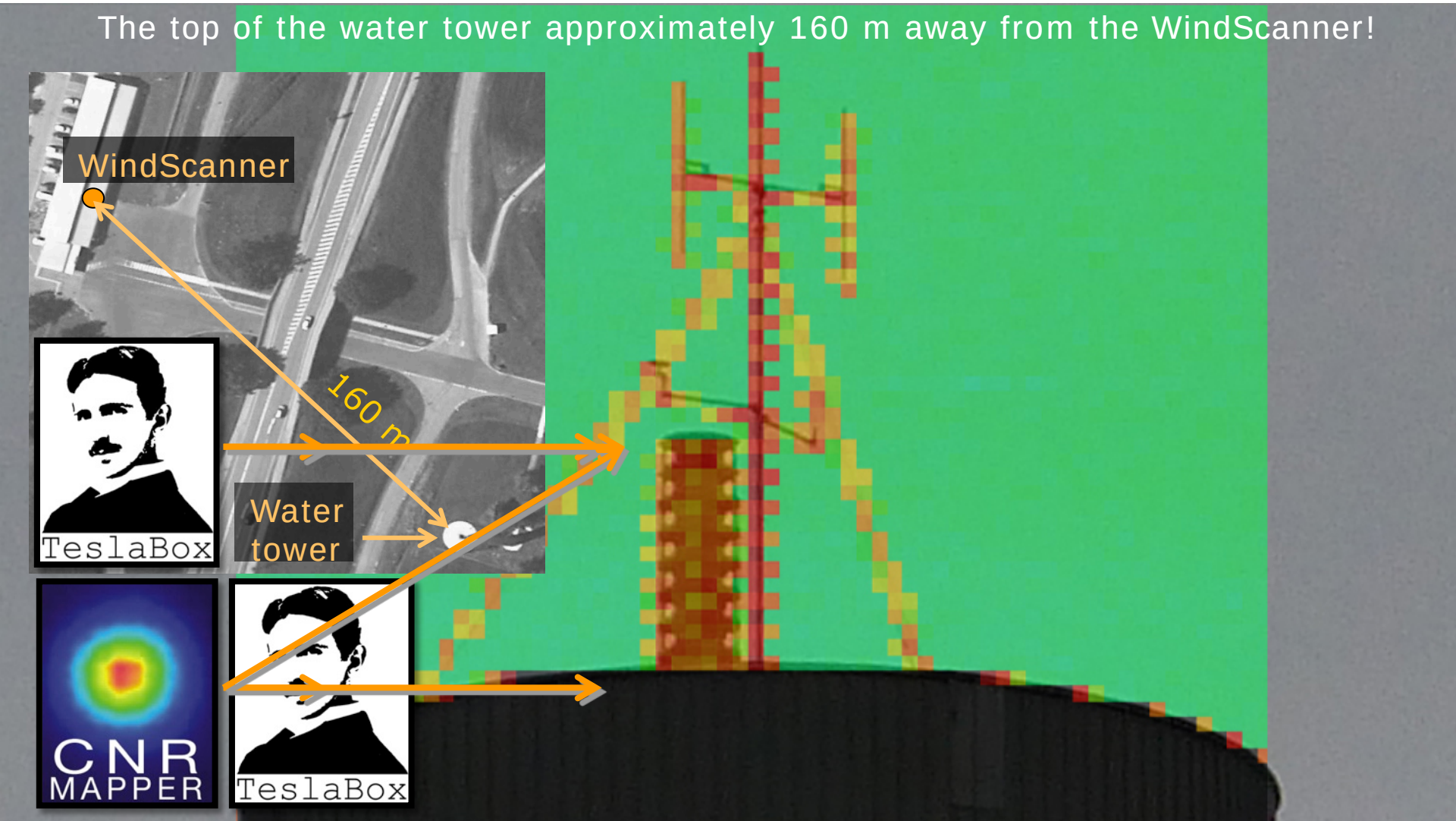
Weighting function



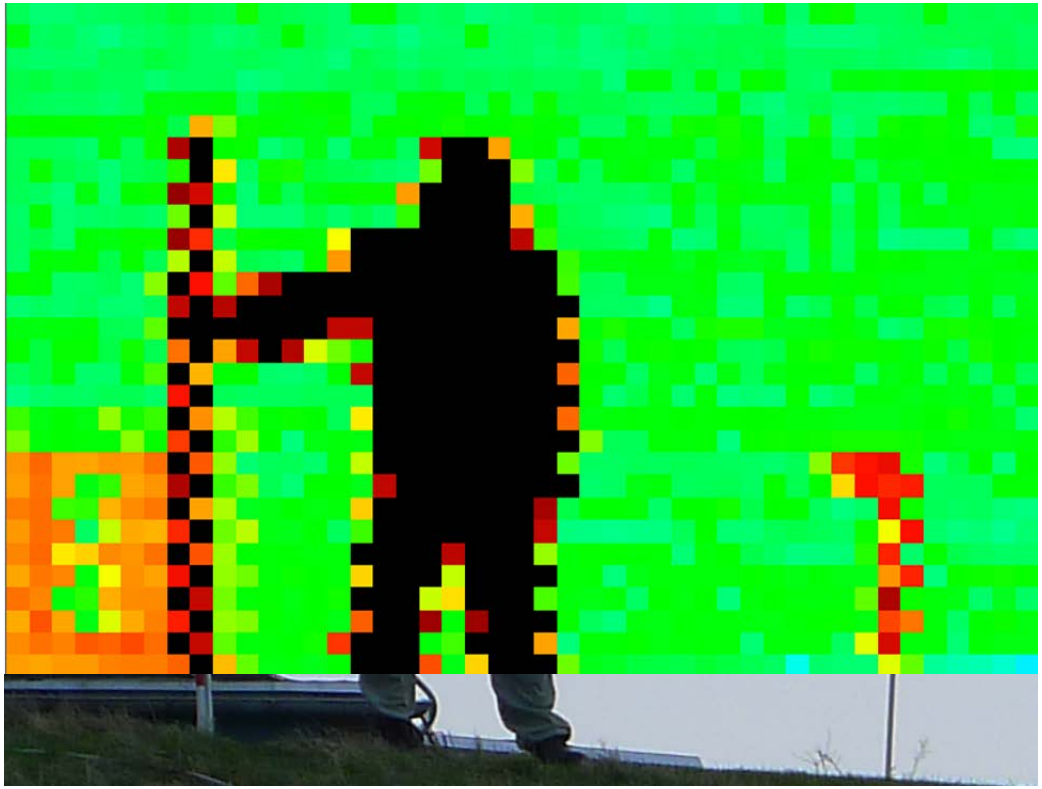
200 ns pulse length, 256 ns window size (64 point in FFT)
CNR shape when hard target is ‘hit’ by the laser pulse

What a WindScanner can see

The top of the water tower approximately 160 m away from the WindScanner!



CNR mapper is fun



Conclusion

- The issue of synchronizing the motion control and the lidar measurements has been elegantly solved by getting **the motion control unit to fire the laser and start the acquisition process as well as controlling the motors for the beam positioning.**

- We have devised **an architecture of a network** of individual WindScanners connected through any type of network interfaces to the master computer that conducts them using **the LidComPro protocol**.

- The synchronization in motion and measurements among multiple WindScanners has been achieved using the GPS clock, crystal clock oscillator and the VaLé compensator with **the maximum lag of 10 ms**.

- We have **freedom in a deployment of the system**, with a possible separation among individual WindScanners of a few kilometers.

- The pointing accuracy will be assessed with **the CNR mapper**.

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Videos: www.youtube.com/cadenza83

WindScanner.dk